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A New Approach to Aeronautical Decision-Making: The Expertise Method

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16. Abstract

Four studies of pilot decision-making were conducted to formulate a general model of the expert pilot that might be applied to novice pilots in order to increase their decision-making skills and reduce their risk of accident involvement. This set of studies began with a series of unstructured interviews of pilots to identify and compile characteristics of the expert pilot. Each succeeding study, then, became more structured in its approach as the characteristics of an expert pilot were more closely defined. From structured interviews conducted as part of the second study, a preliminary definition was obtained that stressed motivation, confidence, superior learning and performance skills, and an intuitive decision-making style. The third study evaluated these characteristics as they were possessed by pilots of three types of relatively high-performance general aviation aircraft. In the final study, experienced pilots were presented with a plausible general aviation flight scenario using a verbal protocol methodology. The responses of the pilots to this table-top simulation were recorded and analyzed. These data suggest that, when compared to competent pilots, expert pilots tend to (1) seek more quality information in a more timely manner; (2) make more progressive decisions to solve problems; and, (3) communicate more readily with all available resources.

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EXECUTIVE SUMMARY

The FAA has been involved in the development and implementation of training programs for aeronautical decision making (ADM) since 1973. The first generation ADM materials focused on the development of an awareness of hazardous attitudes. The students were introduced to the subject of decision making followed by discussions of hazardous thoughts, error chains, and risk assessment. Training manuals were provided with ADM applications to student, instructor, commercial, instrument, and helicopter pilots. An application of ADM to multi-person crews was offered in a crew resource management (CRM) training manual as well.

The current project was composed of four studies designed to formulate a model of the expert pilot that could be tested and used in developing intervention strategies. Each study in turn contributed to an evolving model of the expert pilot. It should be noted that these were exploratory studies, using small numbers of subjects in an effort to define the areas of interest. Consequently, statistical tests and other procedures which may be utilized with more rigorous studies involving larger samples of pilots are not appropriate and are not reported. Nevertheless, the qualitative information obtained from these studies may be of substantial benefit in shaping our thinking about how pilots make decisions and in plotting our future course of research.

During the first study, pilots were interviewed to identify and compile characteristics of the expert pilot. The responses to the initial questionnaire were compiled and characteristics of the expert pilot were placed into categories. These initial categories were skills, procedural knowledge, learning and performance strategies, confidence, and motivation.

In the second study, structured interviews were conducted with thirty pilots who met our initial characterization of expert. From these interviews, a preliminary definition of an expert pilot emerged: "One who is highly motivated, confident (but not overconfident), has superior learning and performance skills, applies those skills in a changing environment, and possesses a type of judgment described by many as 'magic' or 'natural'." Some pilots described the expert as one who becomes "a part of the machine and flows within the 'flying space'." From this second study, a new list of distinguishing characteristics was identified.

The third study evaluated the candidate definition of expert pilot in three types of aircraft from the general aviation mid-altitude flying domain: Beech P-Baron, Piper Malibu, and Cessna P-210. National Transportation Safety Board accident reports were reviewed for these three types of aircraft. Contributing factors in the accidents were used to create a realistic scenario with a set of seven flight events for use in a flight simulation type verbal protocol analysis. Characteristics of each of the events were put in outline form under the general headings: knowledge, skills, and mental models, at three levels: novice, competent, and expert. After this study, the model took the form of a preliminary model of the expert pilot in outline form with the following major headings: knowledge, skills or abilities, behavior, and motivation.

In the fourth study, the scenario developed in Study 3 was presented to subjects and their responses were recorded. The recordings were transcribed and encoded into specific categories for data analysis. The categories chosen roughly corresponded to the major points of the model of the expert pilot developed in Study 3. Frequencies of subject responses in each category were tabulated for later analysis. Trends in these data indicate that pilots who achieved better overall flight results could be differentiated from those who were less successful in three ways: (1) they seek more quality information in a more timely manner, (2) they make more progressive decisions to solve a problem, and (3) they communicate more readily with all available resources. Subjective analyses of the transcripts show that pilots do indeed have different methods and styles for solving fairly common flying situations, and these methods are not related to the total flight time or years flying. These tentative findings are, of course, subject to verification using larger samples in more rigorous, controlled situations. Such replications using similar scenarios in flight simulators are planned which will explore more completely the pilot performance model parameters that these exploratory studies have suggested are important.

A NEW APPROACH TO AERONAUTICAL DECISION MAKING: THE EXPERTISE METHOD

INTRODUCTION

The study of expertise seeks to understand and account for what distinguishes outstanding individuals in a domain from less outstanding individuals in that domain, as well as from people in general. The approach focuses on outstanding behavior that can be attributed to relatively stable, learned characteristics of the relevant individuals. The classical expertise literature suggests that aggregation of experience (e.g., ten years of full time work in a domain) is the single most important factor in the acquisition of expertise (Chase and Simon, 1973). In most cases, no distinction is made concerning the type of experience the expert has had as long as it is acquired roughly in the domain of interest. On the other hand, Ericsson & Smith (1991) found several studies (Libby and Frederick, 1989, Gustafson, 1963) revealing that people with many years of experience in a domain performed only slightly better than those just coming out of training. They conclude that the greatest amount of improvement occurs in training, not as a result of years of experience.

Building cognitive models using the expertise approach involves three steps: 1) Identifying representative tasks that capture the essence of superior performance in a specific domain, 2) Detailed analysis of the superior performance through several methods including verbal reports during performance of the tasks, and 3) Efforts to account for the acquisition of the characteristics and cognitive structures found to mediate superior performances of experts. For a more complete description of the expertise approach, see Downs, Jensen, and Chubb (in preparation).

In aviation the accident record shows that it is in the area of cognitive skills where pilots most often fail. Although general aviation can point to some successful attempts (Fox, 1991; Diehl, 1992), deliberate teaching of judgment skills is rare. Crew resource management (CRM) programs in the airline environment, which are closely associated with aeronautical decision making (ADM) training, seem to be having a useful effect, but assessment strategies are lacking, making it difficult to gage the effects with certainty. It seems clear that the early approaches to ADM training may have reached a plateau. The time seems right for a re-examination of the basic approach to ADM and perhaps to propose new intervention strategies.

The objective of this research effort is to develop new models of ADM to provide a better understanding of the concept in the general aviation domain. From these models, new intervention strategies will be developed, tested and validated. The ultimate objective is safer general aviation operations. The present research effort consists of a series of studies to develop models of the mid-altitude general aviation pilot. In these studies the sub-goals are to 1) determine the distinguishing qualities of expert aviators, 2) assess the processes by which they have acquired their expertise, and 3) create a training and evaluation system to bring the competent pilot closer to the expert. Whereas most previous research on ADM has attempted to change pilot attitudes, the present study was focused on understanding the thought processes of the general aviation pilot. Through the use of several methods of cognitive analysis (performance analysis, expert-novice comparisons, and verbal protocol analysis), an attempt was made to distinguish the qualities of the expert and the competent general aviation pilot. Through this process, a cognitive model was developed. This model will be used to develop a new intervention strategy for teaching these skills.

The domain selected for this study was a subset of general aviation pilots who fly the Cessna P-210 (Centurion), the Beechcraft 58-P (Baron), and the Piper PA-48 (Malibu). These aircraft are considered complex, fairly high-performance single-engine and twin-engine (Baron) aircraft and are usually flown by

a single pilot often in the most complex airspace and in all weather conditions. For these reasons, the flying task for pilots in this domain may be as difficult as any in civilian aviation. To add to the difficulty of the task, many of the pilots of these aircraft have other primary professions (e.g., doctors, lawyers, businessmen, etc.) and do not fly very often and, therefore, may not be as proficient as pilots who make flying their primary profession. These selected models of aircraft have more complex systems and generally fly high-altitude flight envelopes compared to most general aviation light aircraft (Landsburg, 1992). The National Transportation Safety Board (NTSB) reports of accidents for these types of aircraft were examined from the beginning of their respective production programs (Cessna - 1978, Piper - 1984, Beechcraft - 1976). One of the advantages of research in this particular domain is that pilot subjects are available who cover the whole range of expertise. Using the expertise approach taps into their thinking in such a way that many of the results may be generalizable to the entire general aviation pilot population.

Identification and selection of subjects varied for each study in this program. Subjects for each study were selected because they represented the segment of the pilot population being studied and because they had the level of expertise being sought. Some individuals participated in more than one phase of the experiment. This occurred when a pilot was initially selected for the initial and/or the secondary interview and had the prerequisite qualifications for other phases (e.g. flying time in one of the three aircraft representing our domain).

To accomplish the primary objective of this study, to build a model of the expert general aviation aviator, several studies were conducted including 1) literature reviews of the decision making, expertise, and judgment literature, 2) a series of studies using unstructured interviews, structured interviews, cognitive task analysis, and verbal protocol analysis approach, and 3) a modeling design effort. The model of the expert general aviation pilot evolved following each study, first taking the form of a definition of expertise, second, a list of distinguishing characteristics of expert, third, a taxonomy of expert characteristics, and finally, a model for creating the expert aviator.

DECISION MAKING LITERATURE REVIEW

Background

There is a very large body of literature on human decision making; however, most of it is not relevant to the present study. Our review of the literature was restricted to those studies that support our effort to build models of aviator decision making. Our purpose was to determine what others have done in the field of aeronautical decision making and expertise in aviation and other domains and to build on the knowledge base in this study. More complete descriptions of the expertise and modeling research literature are provided in Downs, Jensen, and Chubb, (in preparation) and Chubb and Jensen (in preparation).

Early Judgment Research

As early as 1919 (Henmon, 1919) psychological tests relating to complex psychomotor reaction and attention were used routinely during induced periods of low oxygen in the belief that the results indirectly revealed certain psychological characteristics. During the later stages of oxygen deprivation, there were unusual emotional outbursts of hilarity or anger that many thought revealed basic aspects of the pilot's emotional life or personality. In 1921, researchers (Dockeray and Issacs, 1921) were looking at judgment as part of psychological research in aviation. In a study of the physiological and psychological characteristics of civil airline pilots (McFarland, Graybiel, Liljerfgrahtz, and Tuttle, 1939), evaluation of a pilots' emotional adjustment, temperament, and personality was attempted.

Both psychological and medical research were initiated during the First World War when many pilots failed to complete the training curriculum and the majority of casualties were reported to be caused by human failure rather than by structural failure or combat. The allied countries stressed different aspects of the flying task while developing their test batteries. The Italians studied perception and psychomotor activity while the French stressed the importance of emotional behavior (Dockery and Isaacs, 1921). The British tests were concerned primarily with physiological parameters, but implied certain psychologi-

cal correlations. For example, volition or persistence was judged in terms of the candidate's ability to maintain a column of mercury by blowing into a manometer.

According to McFarland (1953) the limitations of these early studies in aviation psychology included failures, "1) to make job analyses of the requirements for satisfactory performance, 2) to develop methods of rating or measuring flight performance in the air for correlation with tests of selection, and 3) to determine how well the tests actually differentiated good and poor prospects with follow-up studies later in their flying career. Personal judgments rather than experimentally determined criteria for predicting or appraising success or failure characterized the early studies." (page 39)

Pilot Decision Making Research

During the mid 1940s, the growth of aviation medicine, and the need for quick and accurate selection of airmen resulted in a considerable amount of aviation research. Numerous studies referred to "decision making", "judgment", and "pilot error" and implicated the lack of these skills in aviation accidents and incidents. Kelly and Ewart (1942) used scales on the Purdue Scale for Rating Pilot Competency which included both achievement and the intangible factors of judgment and emotional stability. A sample item to assess judgment was "how good is his judgment in deciding to start or continue a flight when adverse factors are involved such as weather?" The continuum of answers was from "extremely cautious," "takes no unnecessary risks," "rarely uses poor judgment," "takes some unnecessary risks," "takes many unnecessary risks," to "extremely reckless." Kalez and Hovde (1953) reviewed the records of pilots and reported on what they called a unique psychological group of pilots who willfully failed to use checklists. They referred to this temporary psychological compulsion as an error in judgment. The pilots who were involved in the resulting accidents presented a long history of non-conformity as evidenced by their flight records. Occasionally, they were below average aviators in every measurable respect. The type of errors in which these investigators were interested were classified as "pilot errors".

The nature of "pilot error" was further investigated by Kunkle (1946). The term refers to all the defects which a pilot may exhibit in all aspects of aviation, although it is limited in that it primarily refers to accident causing behavior. He divided the topic into primary or "non-emergency" error including errors in judgment and secondary or "emergency" error occurring in a setting of tension and confusion associated with a crisis in some phase of flight. Of course, the secondary error may result from an immediately preceding pilot error. However, true emergencies were responsible for only a small minority of pilot error accidents. Kunkle reports that World War II pilot selection tests generally failed to predict those who would have pilot error accidents and that these tests were unable to assess an individual's judgment. He further implies that the problems involved in the operation of an airplane allow full scope for any of the various manifestations of accident proneness. Reviewing the accident background of pilots involved in aircraft accidents revealed a previous accident pattern in which auto accidents were indeed conspicuously frequent. He concludes that there is a direct, but by no means rigid, relationship between past performance on the ground and safety record in the air.

Research into pilot performance, including decision making, continued with Henneman, Hausman, and Mitchell (1947) who studied Air Force pilot performance. In the work on printed classification tests for aircrew members, Guilford and Lacey (1947) report that of all the traits necessary for pilots, judgment stands out as being the most persistent and universal. However, the frequent mention of judgment for the pilot presented a continuing challenge to break it down into manageable components and devise tests for it. Guilford and Lacey concluded that the judgment factor was best defined by a work-planning type of item. Furthermore, items calling for relatively complicated estimates involving time, as well as distance and size, were significantly loaded with the judgment factor while the simpler items were not. The inference which may be drawn is that the judgment factor is a thinking, rather than a perceptual or memory ability. Guilford and Lacey conclude that judgment was highly regarded as a factor and received considerable attention (with varying degrees of success).

Recent Aviator Judgment Evaluation and Training Research

The first research in judgment specifically applied to aviation is a study by Thorpe, Martin, Edwards and Eddows (1976). Situational Emergency Training (SET) was developed for the US Air Force in response to changing the number of crew members from two (in the F-4 fighter) to one (in the equally complex F-15). The SET program was intended to teach the pilot to judge the relevant dimensions of the emergency, maintain control of the aircraft, and to make a decision regarding how to handle the problem. This method replaced the traditional use of memorizing boldface checklist items and was reported to be well received by the Air Force.

Jensen and Benel (1977) present a broad outline for a judgment training and evaluation program. They suggest that the literature outside the field of aviation should be used to develop judgment training and evaluation techniques for pilots. Further, they add that judgment should be divided into intellectual and motivational aspects to establish both training and assessment approaches.

Roscoe (1980) states that individuals have a "pre-set, though modifiable, decision tendency or judgment capability." Included in this consideration of a "judgment capability" are the person's intellectual and emotional capabilities, priorities, self-esteem and pride. "The pilot who has been trained to assess flight alternatives objectively and act accordingly in all flight situations may be said to possess good flying judgment." If this is the case, then the problem becomes one of identifying, measuring, and training the skills necessary to use good pilot judgment.

A review of research by Giffin and Rockwell (1984) shows preliminary work in designing and implementing a computer-assisted testing device for studying specific types of pilot decision making. Tests of a variety of candidate hypotheses concerning the style and substance of pilot resource management and decision making were used to:

1. Ascertain the role of pilot background, experience, and knowledge in problem diagnosis and decision making; and
2. Describe the problem solving paths in sufficient detail to permit the ultimate development of various models of pilot behavior.

Giffin and Rockwell measured pilot response to critical in-flight events (CIFE) using a computer aided scenario testing system (CAS) in a test of forty-two subjects with varying levels of flying experience. Subjects first entered biographical data, then took a knowledge test of aircraft systems and operations. In the diagnostic scenario procedure, the subject was told that he was flying a Piper Cherokee Arrow with information on equipment and performance displayed. The next display revealed the nature of the mission and symptoms of a problem being encountered. The subject then had four minutes to seek information and generate a diagnosis. There were four diagnostic scenarios. When the time was up or a diagnosis had been entered by touch pane entry, the time history of the information search was immediately available to the experimenter. Relevant findings in the study included (1) knowledge was inversely related to diagnostic inquiries, i.e., knowledgeable pilots reached conclusions (right or wrong) more rapidly than others; (2) less experienced pilots tended to use a larger number of diagnostic tracks than did the more experienced pilots; and (3) pilots followed a wide variety of different search patterns during diagnosis.

Berlin et al., (1982) provided the initial work for the writing of the prototype "Judgment Training Manuals" used in a series of tests by the FAA. The manuals were designed to improve judgmental behaviors through a modified behavioral approach applied through instructor pilots. Five "hazardous thought patterns" were identified and applied using flight scenarios. The students were to learn how to identify these hazardous thought patterns and to replace them with more rational thinking.

A validation study using the "Judgment Training Manual for Student Pilots" was performed by Buch (Buch and Diehl, 1982) on Canadian Air Cadets. A select population was chosen from two standardized flight academies in Canada. In knowledge tests both control and experimental groups were found to be adequate and equal in skills and knowledge. The

results of the experiment show that the experimental group receiving the judgment training consistently made "better" decisions than the control.

Additional judgment training manuals have been developed for specific pilot populations in civil aviation. Jensen and Adrion (1984) developed a program of aeronautical decision making for instrument pilots and Jensen, Adrion and Brooks (1986) developed a manual for aeronautical decision making for commercial pilots.

Jensen, Adrion and Maresh (1986) studied the effectiveness of the application of the "DECIDE" model to aeronautical decision making. The "DECIDE" model of decision making is a concept of the cognitive judgment process consisting of six elements arranged in a closed loop system. "DECIDE" is the acronym for Detect change, Estimate significance of change, Choose outcome objectives, Identify plausible action options, Do best option and Evaluate progress. The preliminary results in this evaluation indicated the model has great potential as a judgment training tool in aviation. The "DECIDE" trained subjects demonstrated clearer thinking patterns in diagnosing the experimenter induced problems during a simulated flight in a general aviation flight simulator. They also showed greater concern for the safe outcome by successfully landing the "aircraft."

A consistent conclusion in the majority of the aviation decision research has been the need for continued study in the area. Livak (1983) reviewed current literature and proposed four types of activities necessary for pilot judgment training. First, education should include a non-mandatory judgment training program for all pilots. Second, training needs to provide specific information and judgment skills required for a particular license or rating. Third, certification requirements should assure that the applicant possesses and can demonstrate sufficient judgment. And, fourth, there needs to be a rehabilitation component for those airmen who have been involved in an accident, incident, or violation in which the investigating official felt the causal factors were related to poor judgment.

There are numerous studies that relate, at least in part, to the subject of training and evaluating pilot judgment. Trollip and Ortony (1977) offered insight into real-time simulation in computer assisted instruction that is applied to aviation. A simple conversion of a classroom training program can provide a program for computer assisted instruction (CAI).

Personality studies by Lester and Bombaci (1984) and Ashman and Telfer (1983) correlated certain attributes with pilots. These studies may be useful when comparing the personality profiles of pilots involved in accidents and incidents with selected profiles of the general population to determine if there are any particular similarities of perhaps neurotic or psychotic individuals. To date this determination has not been made.

Sociological factors have also been considered with respect to pilot error as found in the works of Urban (1983) who looked at the urban/rural differences of pilots involved in accidents. The universality of the problems encountered in aviation due to human error is evidenced in the research efforts in many countries outside of the United States.

Ground (1984) found pilot-induced factors to be responsible for 69.3% of the fatal light aircraft accidents in the United Kingdom from 1969-1981. The position was taken that accidents do not just happen - they are caused. A number of factors were included when discussing pilot error including; forgetfulness, carelessness, irresponsibility, procrastination, pride, ignorance and incompetence. An important overall characteristic of judgment-caused accidents was that these accidents seldom had a single cause.

"Pilot Error" in Accident Investigation

Due to imprecise past measurement techniques in accident and incident causal factors, new methodology to address these problems has recently been established by the US Air Force. Accident investigation can be a useful adjunct to judgment evaluation training, testing, and tracking. Therefore, some of the terminology and investigative processes used in the new Air Force accident and incident evaluations are discussed in this section. This information is incorporated into the framework used in the development of the Jensen Adrion Maresh Judgment Evaluation Technique (JAMJET).

The dichotomy between training and accident reporting with respect to human factors in the Air Force has been apparent since the early training days. The

cause of an accident may be classified as "human error", though no description of the type of human error is given. Was it failure of the pilots' perceptual system, lack of knowledge, physiological failure, or a series of poor decisions? The current work on development of an accident reporting system congruent with current aeronautical decision making training programs will add greatly to the understanding of the human factors problems. It is this understanding of the nature of problems which cause accidents that enhances our awareness of the deficits pilots have in these abilities.

New guidelines are currently being established for accident investigation team members which include precise definitions, documentation and thorough evaluation of the "psychological concerns" as one of the areas of concentration. A workbook has been designed to aid in the standardization and recording of all factors involved in a mishap including the human factors arena. In this context, a mishap is an unplanned, unintended event that results in damage to equipment or injury to personnel. Mishaps are broken down into specific categories, antecedent events, maneuver, and the phases of flight.

As a team member in accident investigations, the human factors/psychological specialist is directed to examine human factors including perception, information processing, attention, perceived stresses, fatigue, coping styles, psychomotor capabilities and training. A distinction is made between "technical errors" and "judgmental errors" usually involving higher-order cognitive processes. Technical errors are objectively inappropriate individual physical or mental operations such as missing a radio call, inaccurate altitude or airspeed or improper switch or control operation. Judgmental errors are objectively inappropriate selection of a course of action constituted by a number of subsequent subtasks. Examples include making an approach to below minimums or accepting an aircraft or personal condition inappropriate to anticipated mission demands.

Types of errors. Morris and Rouse (1985) differentiate between "slips" and "mistakes" as types of human errors. Slips are considered errors of action occurring during a well trained activity. The slip is usually brought on by a distraction or a preoccupation. Since these errors occur in well established routines, they are usually unmonitored. When they do occur and are subsequently discovered, they add to the distraction. Specific types of slips include habit pattern interference, perceptual set, and omission or repetition of steps in a sequence (e.g., checklist items being skipped, or repeated.)

A "mistake" type of error concerns judgment and decision making issues. Judgmental errors are likely when more than two or three variables must be simultaneously considered. They may also occur when an inappropriate solution has been successful in past similar situations and when solution options are novel. Poor judgment is considered to be the failure to realistically assess the significance and priority of information from the environment. Assuming adequate quality and quantity of information, the poor judgment is due to an anomaly of attention or anomaly of motivation.

Attention and Motivation. Anomalies of attention are the misallocation or untimely interruption of attention to a task easily influenced by fatigue or other stressors. The types of anomalies of attention include channeled attention, cognitive saturation, distraction, fascination, inattention and habit pattern interference or substitution. Anomalies of motivation are characteristics of a person's value system which may result in unsafe acts. Types of motivation anomalies include excessive motivation, under motivation and misplaced motivation.

Workload and Stress. Workload is considered for investigative purposes as contributing to errors. Perception of the amount of stimulation as too little or too much will have an effect on the number of errors. On the other hand, Hart and Bortolussi (1984) considered pilot errors as a source of workload rather than a symptom. This viewpoint may be advantageous when reconstructing the sequence of events in a mishap. Thus, the occurrence of mistakes and slips add to the mental workload.

Another view of the mental workload involved in the specifically active and adaptive responses to the demands posed by a complex task is offered by Wiener (1985). To identify the operational components of the central mechanisms involved in information handling and decision making, the subsystem components

were distinguished. This enables a measure of the stress undergone by each subsystem. "Stress", in psychological terms means the active responses which are specifically adaptive or adjusted to the external stress which maintains homeostasis. Psychological homeostasis is an ability to "cope" however intense the performance level that is its cost or stress. "Strain" is evident in the non-maintenance of homeostatic levels. In other words, under strain the pilot is asking to be overstressed. Psychological strain is shown by the inability to "cope" with the imposed load or stressor.

The breakdown of the system is as follows:

1. The discrimination subsystem is where incoming signals are recognized and coded. The demand (stress) placed on this coding system could be quantified in terms of the number of identifications per unit time.
2. The decision making (or choice) subsystem connects the identification subsystem to the output subsystem. The rate at which connections are made for passing on the coded input signals is the measure of the response or the stress placed on this subsystem.
3. The output subsystem is the number of central output signals per unit time sent to the executive muscles for the performance of the task. The rate of output is a measure of the response or stress placed on the system.
4. The corrective feedback subsystem regulates the accuracy of the output. The operation is assessed in terms of errors made in performing a set task, but error evaluation is more properly regarded as a measure of strain.

Generally, the measure of response to a mental task is restricted to only the output system as a measure of stress. A measure of strain could be taken at the corrective subsystem. One special category of internal factors needs also to be considered in this general model. These host factors include the phases of the circadian rhythm, time period (pre- or post-weekend, holidays), quality of sleep, repetitiveness of the task, change of shift, and relationship to meals. Drug and alcohol use can be included here as well. These factors influence the psychological response and add to or modify the internal stress system.

Jensen Adrion Maresh Judgment Evaluation Technique (JAMJET)

Figure 1 is a detailed model that describes a series of eight steps in the decision making process. This model is an adaptation of an eight-step judgment model first offered in a report for the US Air Force (Jensen, Adrion, and Maresh, 1987) and later presented in Jensen (1995). This model is specifically designed to describe the aviation cognitive judgment process. Understanding each step and how the steps are interrelated is important to the development of better prescriptive models needed for intervention development. The complete description of this process as offered in Jensen (1995) is not necessary here. For our purposes, it presents a picture of our understanding of the information processing aspect of aviator decision making that must be examined in this program. The blocks indicate the steps in the process and the descriptors on the right indicate mental factors that enter into each step.

A more practical model of pilot judgment was presented in the Jensen and Benel (1977) report. This model had two parts: 1) an ability and 2) a motivation as shown below:

Part I: Rational Judgment:

The ability to discover and establish the relevance of all available information relating to problems of flight, to diagnose these problems, to specify alternative courses of action, and to assess the risk associated with each alternative.

Part II: Motivational Judgment:

The motivation to choose and execute a suitable course of action within the available time frame.

Where:

a. The choice could be either action or no action and,
b. "Suitable" is a choice consistent with "societal" norms.

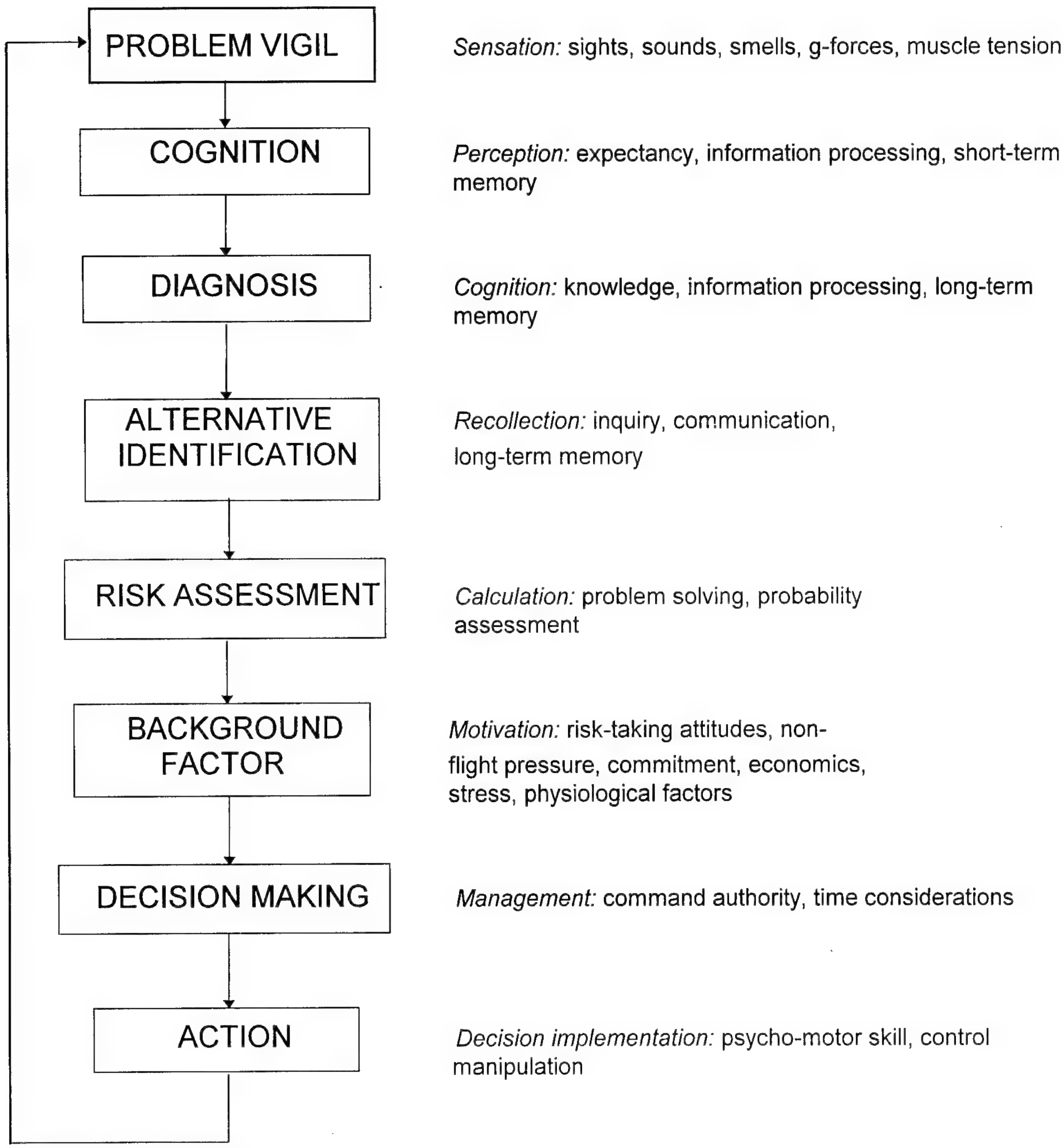

Figure 1. Detailed judgment model (Jensen, 1995)

Rational Judgment. The first part of good pilot judgment is the mental ability of the pilot to detect, recognize, and diagnose problems, to establish available alternatives and to determine the risk associated with each alternative. This part is purely rational, and if it could be used alone (which is not possible), would allow problem solving using mathematical functions in much the same manner as a computer. This does not mean it would be error free; it uses information that is probabilistic and therefore, predicts outcomes that are not certain. In addition, rational judgment depends upon the amount, type, and accuracy of the information stored in the pilot's memory as well as his or her learned capabilities to retrieve and process information. To optimize rational judgment requires high levels of knowledge, experience, organized mental structures, and systematic computational and problem solving abilities.

Motivational Judgment. The second part is the motivational or bias aspect of judgment. The emphasis is on the directional, rather than the aspects of motivation dealing with intensity. This part of judgment says that humans (and pilots) base their decisions, in part, upon bias factors or tendencies to use less than purely rational (as defined by society) information. These factors include immediate gratification such as ego, adventure, commitment, duty, social pressure, and emotional arousal in the form of worry, fear, stress, anxiety, and euphoria, as well as more long term biases such as risk-taking attitudes, and personality factors (e.g., fear of failure and defensiveness). Optimizing motivational judgment requires both 1) an awareness of biasing factors and 2) a will (motivation) to suppress these error producing factors so that decisions can be made on the basis of relevant safety factors from the physical world.

At this time, the rational aspect of pilot judgment has received very little attention. However, there is much in the literature outside of aviation including stock brokers, livestock judges, and medical diagnosticians, indicating that this aspect of judgment can be taught. In each of the areas studied, judgmental training occurs over a fairly long apprenticeship program in which the trainee observes the expert making decisions and learns by these observation. Rouse and his colleagues have performed a series of experiments to develop fault diagnosis training systems to be administered on computer (Rouse, 1979). As mentioned earlier, one demonstration study at The Ohio State University (Jensen, Adrion, and Maresh, 1986) has shown the effectiveness of the DECIDE model in teaching rational judgment to pilots.

On the other hand, the motivational aspect of pilot judgment has received the bulk of research. Early efforts following the Jensen and Benel study focusing on this part of the model have shown that motivational training can be effective. The model used in all of these studies may be called the attitude model or five hazardous attitudes: Anti-Authority, Impulsivity, Invulnerability, Macho, and Resignation. An awareness of these attitudes, that are found to some extent in everyone, can help to develop a more positive and rational approach toward flying decisions. Training studies using this model have demonstrated that pilot decision making improves anywhere from 13% to 100% as a result of attitude training (Buch and Diehl, 1982; Telfer, 1987; 1989; Diehl and Lester, 1987; Diehl, 1992; Fox, 1991; Alkov, 1991). Impressive results have also been reported in two helicopter operational training studies. Petroleum Helicopter Inc. (PHI) and Bell Helicopter have both offered the attitude method of judgment training to large numbers of helicopter pilots. PHI has reported a 54% reduction in accidents after giving this training to their pilots. In two studies, Bell Helicopter reported a 36% decrease and a 48% decrease in accident rates after the training. Both organizations point to the judgment training as the most important tool now available to improve safety in helicopter flying.

However, attitude training as it is formulated in the original Embry-Riddle Aeronautical University manuals (Berlin et al., 1982) has negative connotations and its benefits seem to have reached a plateau. Alternative approaches are needed which focus on the other half of the Jensen and Benel model emphasizing information processing. This new emphasis requires fundamental research into human decision making and modeling.

Expertise Research

A prerequisite to this project was a definition of the "expert" pilot. The current literature on expertise in aviation is rather limited; therefore, a review of the research on expertise in other domains was conducted as well. The full range of methods of analysis in cognitive psychology and cognitive engineering can be applied in the examination of phenomena associated with a particular type of expertise. These include performance analysis, expert-novice comparisons, and extensive studies of single subjects. The identification of a collection of tasks that can capture superior performance is often not easy. This study used a large number of tasks for the subjects studied.

Experts engage in a number of complex mental activities, involving the ability to plan and reason, that rely on mental models and internal representations. Charness (1981) found that the depth to which a possible move sequence for a chess position was explored was closely related to the level of chess skill. Charness (1989) found that expertise at the game of bridge was closely linked with the capacity to generate successful plans for playing the cards in the optimum order. Similarly, in medical diagnosis, many different pieces of information from different sources must be integrated. Since this information is not available at the same time, the internal representation of the presented medical information must be sufficiently precise to allow extensive reasoning and evaluation of consistency, but also must be sufficiently flexible to allow reinterpretation as new information becomes available (Lesgold et al., 1985).

Sloboda (1991) made the distinction between "routine" and "adaptive" expertise. Routine expertise is the reliable attainment of specific goals within a specific domain. Whereas routine experts are able to solve familiar types of problems quickly and accurately, they have only modest capabilities in dealing with novel types of problems. Adaptive experts can make an appropriate response to a situation that contains a degree of unpredictability and may be able to invent new procedures derived from their expert knowledge.

Expertise theory has been evolving since the late 1950's with as many theories proposed as there are theorists. Early research on decision making stressed mathematical models that either measured decision biases or used game theory and economics. Traditional research evolved from two paradigms, formalist-empiricist and rationalist. Formalist-empiricist research focused on behavioral testing of formal models and neglected the cognitive processes underlying the subjects' decisions. The rationalist approach establishes a formal view of normative standards and accounts for reasoning in terms of a set of unrelated cognitive mechanisms. Experimentally this approach demonstrates the errors that take place between the normative model and the actual decisions.

In an effort to make the decision research useful in context, the Army Research Institute Office of Basic Research (Johnson, Rouse and Rouse, 1980), began investigating planning, problem solving, and decision making in naturalistic settings. These research methodologies focus on decision processes taking place in realistic, dynamic, and complex environments and their real-world outcomes. The naturalistic paradigm investigates the way people actually respond to complex environments targeting the functions that cognitive processes serve. Whereas decision biases in the traditionalists' viewpoint are violations of consistency constraints imposed by the theory or norm, the naturalists view decision errors in the real settings differently. The naturalistic approach emphasizes cognitive representations and processes, but as Cohen (1993) explains "evaluation of reasoning is more subtle and demanding: no longer a cookie-cutter comparison between performance and an unquestioned normative template. In the naturalistic framework, the reciprocity between normative and descriptive concerns that characterized the formal-empiricist approach can be retained...if cognitive as well as behavioral criteria are incorporated into normative modeling." (Page 50).

Moving from the theoretical to the applied research, Adams (1993), in a summary of the expertise literature offers seven basic characteristics of what he terms "Expert Decision Making" which are relevant to experts in all domains. These are:

1. **Superior memory.** Expert's recall seems to exceed the limits of short-term memory. Autonomous information processing frees up greater storage. Experts

excel in long-term memory as well. Elaborations, associations and inferences expedite recall.

2. **Goal oriented.** The knowledge of experts is highly goal oriented. Concepts are bound to procedures for their applications and to conditions under which these procedures are useful. This functional knowledge is strongly related to task demands and goals invaluable in problem solving.
3. **Fast access.** Experts can solve problems more quickly and accurately than non-experts. They are faster at skill-based tasks, these tasks require less attention capacity, and they have more time to do cognitive tasks. They arrive at solutions without conducting an extensive search of memory.
4. **Opportunistic planning.** Experts can revise production rules and simultaneously access multiple interpretations of a situation.
5. **Adaptive.** There are both routine and adaptive experts. Both have outstanding accuracy, speed and automaticity in decision making and problem solving. Routine experts are more limited in their capability to perform new or ill-structured problems. Adaptive experts have the ability to creatively respond to ill-structured or ambiguous new problems with a considerable chance to find a successful outcome.
6. **Self-monitoring.** Greater knowledge bases and different knowledge representations of experts allow more time to predict problem difficulty on the basis of underlying principles and to monitor how they should allocate time and resources to solving the problem. Experts are more sensitive to informational feedback useful to problem solution.
7. **Perceptual superiority.** Experts have the ability to perceive meaningful patterns using the organization of their knowledge base. Pattern recognition occurs so rapidly that it takes on the characteristics of instantaneous insight or intuition.

In his effort to develop a personality instrument to profile "safe" and "unsafe" pilots, Rodgers (1994) developed another model of the expert pilot. In his model an expert pilot is an individual who allows for few errors, possesses almost total objectivity, excellent perceptiveness, and a tolerance for risk without any tendency to pursue risk for its own sake. The expert pilot must maintain the ability to compartmentalize and prioritize demands throughout the spectrum of situations from boredom (repetition) through total mayhem (the unexpected, unknown emergency).

The current study, though, addressed from the viewpoint of expertise literature, the question, "What does an expert pilot do (or not do) that an average pilot does or does not do?" Building upon the previous research, this study sought to develop a better, operational definition of an expert pilot, to delineate the characteristics of expert pilots that differentiate them from novices, and to examine the degree to which pilots who might be regarded as experts possess those characteristics. To do this, we accomplished a series of studies moving from general, loosely structured exploratory studies to more tightly controlled experimental procedures.

The project was composed of four studies. During the first study, pilots were interviewed to conceptualize a working definition of the "expert" pilot. The second study consisted of administering a structured interview to thirty pilots who met the criteria of "expert" pilot from the initial unstructured interviews. The third study of the project evaluated the candidate definition of "expert" pilot in three types of aircraft making up the mid-altitude flying domain: Beech P-Baron, Piper Malibu, and Cessna P-210. National Transportation Safety Board accident reports were reviewed for these three types of aircraft and an experimental flight scenario was developed. In study four, the entire scenario was read to subjects and their responses were recorded. The recordings were transcribed and encoded into specific categories for data analysis. All four of these studies are discussed in detail in the following sections.

STUDY 1
SEMI-STRUCTURED INTERVIEWS

The first study consisted of a set of semi-structured interviews to begin the quest for an understanding of expertise in aviation and to determine workable terminology to be used with aviators in discussing expertise. From these interviews, three levels of pilot

performance emerged which were given the designations of "below-average", "average", and "above-average". To date, this terminology has proved useful in discussions with pilots concerning expertise. These interviews also investigated possible representative tasks for use in evaluating above-average performance in aviation by eliciting critical event scenarios from the subjects.

Subjects

The initial semi-structured interviews were administered to 10 highly experienced pilots with an average number of years flying of 32.5, and average total flight time of approximately 13,500 hours. All of the interviewees were flight instructors and six were also designated pilot examiners. These same individuals agreed to participate in future phases of the project.

Procedure

The initial verbal protocol analysis for aviators began with the questionnaire shown in Appendix A. This instrument was designed to elicit responses from the subjects to aid in the establishment of working definitions used in this project (e.g. "expert pilot", "novice pilot"). The questionnaire was given orally to each individual pilot as a part of the interview and their responses were recorded by the experimenter. The questions were open ended and participants were encouraged to expand and elaborate on their answers.

Results

The following is a summary of the ideas provided by the 10 pilots in the preliminary interview organized along the lines of the topics requested:

1. How can you distinguish how "good" a pilot is?
   "How do you know you are in love?"
   "Good pilots are a part of the machine."
   "They have a feel for it."
   "A good pilot can put it all together, they have the rote knowledge, understanding, and ability to apply this."
   "A good pilot is smooth, doesn't jerk, can anticipate what he is going to do and is methodical"
   "A good pilot coordinates well."
   "Confidence and smoothness."

2. If you were to group pilots into three categories based on how "good" they are, what would you name the categories?
   Category A. *Ace, professional, natural, good, above average, accomplished, best, unique.*
   Category B. *Run of the mill, mimic, competent, average, comfortable.*
   Category C. *Worst, poor, amateurs, dangerous, rote, below average.*

3. What did you base your categories on?
   Categories were established primarily by answering the first question. Ability to explain, understand his machine, and the ability to verbalize.
   "What I have seen."

4. Describe a "Category A" pilot. Can you name three?
   "Confident."
   "Good stick and rudder, and can fly big and little airplanes."
   "Has the "magic" which is imagination with respect and awe."
   "Always a student of aviation."
   "Has a strong desire to fly."
   "Part of the aircraft."

5. Describe a "Category B" pilot. Can you name three?
   "Proficient stick and rudder, but unaware."
   "Safe enough to get there and back."
   "Not really with the aircraft."

6. Describe a "Category C" pilot. Can you name three?
   "Poor attitude control."
   "Mechanical pilot."
   "Can't put mechanical skills together with what's going on."
   "Dangerous."
   "Doesn't keep up with anything."
   "Narrow field of inquisitiveness."

7. What is the best maneuver to use to determine how "good" a pilot is?

The maneuvers mentioned were lazy eights, once around the patch, the FAA weave, ILS, minimum controllable airspeed, and steep turns.

8. Name the three most memorable events you have had as a crewmember in any aircraft.
   This question was asked to begin a collection of "critical incidents" and were gathered for future research use. The responses were both positive (enjoyable) events and negative (emergencies encountered).

9. Would you be willing to participate in future phases of this project?
   All initial participants were willing to continue participation.

Discussion

From these responses several candidate definitions of the levels of pilot expertise emerged. It was clear from discussion with these very high-time instructor and examiner pilots that there is a need to differentiate between types of skill needed to be an "expert" aviator (i.e., mechanical skills, knowledge, and judgment). One theme that was repeated frequently was that "farm boys often make above average pilots, but just because he can drive the tractor doesn't make him an astronaut." From our analysis of the semi-structured interview results, the following definitions were developed:

STUDY 1
INITIAL DEFINITIONS OF THE ABOVE AVERAGE PILOT

Skills:
1. Mechanical ability - either natural or learned, (innate vs. trained)
2. Reasoning - assimilate information, process information, and perform

Procedural Knowledge:
1. Aircraft systems (must know pilot operating handbook)
2. Rules (regulations, operations specifications)
3. Procedures for maneuver
4. Anticipation (Situational Awareness)
5. Strategies and planning

Learning and Performance Strategies:
1. Desire to excel and perform in aviation
2. Focus and ability to focus
3. Situational awareness within the time frame
4. Decision making
5. Practice (even a "natural has to practice")
6. Goal to be the best possible and always working toward that goal
7. Keep expanding goals - always a student of aviation

Confidence:
1. Good ego strength ("I can do it")
2. Not over confident
3. Dedication to task
4. Confident enough to admit an error

Motivation:
1. Ego factor - drives them to be the best
2. Do it for yourself
3. Enjoys the challenge of flying
4. Perceived money and prestige
5. Wants freedom and control
6. Has the "X" factor (Indescribable "magic")

In summary, the initial results of semi-structured interviews provided suggestions for terminology to be used in further interviews and in verbal protocol simulations. After much discussion and review of other studies (Ericsson and Smith, 1991; Dreyfus and Dreyfus, 1986), we decided to use "above average," "average," and "below average" as the three classifications of pilots while working with the subject-pilots in subsequent studies. Our abbreviated definitions of these terms were:

Above Average: *Highly motivated, confident (but not overconfident), superior learning and performance skills, has the "magic."*

Average: *Adequate learning and performance skills to complete the task.*

Below Average: *Lacking in motivation and/or the ability to learn and/or perform consistently.*

STUDY 2
STRUCTURED INTERVIEWS

The second study consisted of structured interviews with a different set of pilots who were engaged in instructing and/or evaluating pilots. All had experience in the three aircraft making up the domain. The purpose of these interviews was to investigate the cognitive processes and learning strategies of the above average pilot in order to refine our working definition of aviator expertise and develop distinguishing characteristics of the expert in this domain.

Procedure

Thirty highly experienced pilots (average flight time of over 5,000 hours) were interviewed using the Structured Interview form shown in Appendix B. Subject responses were recorded by the experimenter. The interview format was again open-ended as in Study 1. Questions were added to investigate the motivational aspect of pilot continuous learning, which subjects in Study 1 had indicated was an important factor in above average pilots. The responses were compiled and analyzed.

Results and Discussion

The responses to the structured interviews were extensively reviewed for repetitive answers and statements across the participants. A strong theme and pattern to the interviews emerged leading to a preliminary definition and a set of distinguishing characteristics of the expert pilot in this domain. The preliminary definition of an above-average or expert pilot is one who is highly motivated, confident (but not overconfident), has superior learning and performance skills, applies those skills in a changing environment, and possesses a type of judgment described by many as "magic" or "natural." In pilot language the expert pilot becomes "part of the machine and flows within the 'flying space'." The pilot expert in this domain is one who:

1. Possesses self-confidence in his or her skills as a pilot,
2. Is highly motivated to learn all there is to know about the flight domain and practices their skills constantly,
3. Has superior ability to focus on the necessary task and change that focus at the slightest hint that a change is needed,
4. Has excellent situational awareness (flight environment, location of other aircraft, terrain, navigation, communications, weather, etc.),
5. Is highly cognizant of the machine including noise, vibration, and engine indications,
6. Is always vigilant for the unusual, abnormal, or emergency, and mentally makes contingency plans,
7. Has superior mental capacity for problem diagnosis, risk assessment, and problem resolution,
8. Has excellent communication skills and applies those skills to each audience and situation,
9. Knows his or her own limitations and is motivated to keep a safe margin above that limit, and
10. Has the ego-strength to enforce his or her own limitations in every situation.

Responses to the critical incident questions provided numerous examples of tasks to test for expertise in this domain including: reported gear and gear indication problems, pressurization abnormalities, aircraft control at high altitude in turbulence, and system operations (auto-pilot, avionics, standby gyros).

From these characteristics an expert aviator analysis was performed establishing abstractions about the tasks involved in expert flying. The tasks identified were classified as skills, knowledge, and mental models. Most of these components were found to be domain specific and included perceptual-motor skills, procedural skills, and knowledge about the domain and all related domains (e.g. weather, air traffic control, physiology, etc.). Other components may be domain specific, but also could be carried across domains in expert behavior. These qualities are mostly descriptive of the mental models and include motivation, judgment (decision-making skills), and communication skills. Additional traits contributing to the ability of an expert aviator to exhibit his expertise are those of maturity in thought and action, consideration of man and machine, honesty to self and others,

and smoothness in control of the aircraft. These qualities may be considered more style than factors in expertise, though the concepts were considered important by many of the interviewees.

Three factors were found to be important in distinguishing the "expert" pilot from the "average" pilot: 1) their method of information acquisition, 2) their decision processes, and 3) their communication skills. From this we hypothesized that 1) the expert pilot will seek more and better quality information about the task at hand and will seek more information regarding the changing state of the situation than the competent pilot, 2) the expert pilot will make more decisions than competent pilots, and 3) the expert pilot will communicate more efficiently with all of the potential resources for decision making than the competent pilot. Study 3 was then designed to evaluate these hypotheses.

STUDY 3
EXPERT AVIATOR ANALYSIS

One expert mental model that applies to all domains has not been developed. The literature indicates that expertise is highly domain specific and that it is unlikely to yield a model that can be applied across domains. The literature on naturalistic decision making indicates that, in the acquisition of expertise, a transformation of qualitative knowledge organization takes place as the novice progresses to expertise. This suggests that expertise in any domain must be taught as a series of steps leading to the expert mental model. Thus the structure of the expert aviator analysis may consist of three progressive acquisition phases: knowledge, skills, and mental models. The initial evidence in our investigation of the expert aviator suggests that the input and output for the "expert model" is domain specific, while the process from novice to expert is general across most aviation domains.

Following Ryder and Redding's (1993) process on integrating cognitive task analysis into instructional systems development, in Study 3 a novice to expert progression analysis was performed on the verbal responses of six domain-experienced pilots using a scenario developed specifically to test for the characteristics identified in the previous stage. The analyses of each of the seven events of this scenario were established through close adherence to aircraft operating manuals, standard operating procedures, Federal Aviation Administration guidelines and rules, published training manuals, and additional materials applicable to the task. The focus of the analyses was on the mental models which were used to establish performance criteria for each subject on each task. These criteria are not subjective evaluations of the outcome, but measures of how closely the subjects' encoded responses matched our model of the expert pilot.

Simulation Scenario Development

The scenario written for the project was developed after an in-depth study of the accident reports from the NTSB on the three domain aircraft. Accidents in the three domain aircraft from the beginning of production of each through 1992 were reviewed. Contributing factors to the accidents were compiled into major areas to be used in the simulation scenario. The most significant problems identified in these aircraft were: weight and balance, fuel planning, system abnormals in instrument meteorological conditions (IMC), suspected in-flight break-up, effects of icing, flight into adverse weather conditions, and controlled flight into terrain. From this list of problems we identified those that could be simulated easily and also would discriminate competent pilots from experts. The seven events that we identified for the simulation scenario were:

1. Performing a weight and balance assessment and checking fuel.
2. Landing gear abnormal on take-off.
3. Icing conditions during climb-out.
4. Hypoxia at altitude.
5. Unexpected holding with moderate turbulence on arrival.
6. Reported windshear conditions on approach.
7. Landing gear abnormal on landing.

These seven events were then assembled into our experimental flight scenario. The text of the scenario is presented in Appendix C.

Event Analysis

Table 1 presents an analysis of the factors identifying the progression from novice to expert for the seven scenario events used in the Study 4 experiment. These outlines break-down the specific experimental events into knowledge, skills, and mental models. The outlines progress through three developmental stages with the definitions at each level being slightly different. The knowledge progression begins with domain concepts, rules, and procedures. It then proceeds to declarative knowledge structure, and then to expert knowledge organization. The skills advance from the basic necessary skills, through competent skill components, to the refinement of these skills. Mental models are the deductive framework for problem solving providing the structure for knowledge and skill organization and utilization in the domain. In the analysis of data in Study 3, presented below, we subjectively determined the extent to which each subject's behavior corresponded to the level of expertise identified by these factors for each event.

Table 2 presents a general list of factors identified with aviator expertise in this exercise based on situation assessment, conditions, and prerequisite information specific to the scenario. Table 3 presents a new reformulated model contrasting the characteristics of the competent and the expert general aviation pilot. In combination these factors and models were used as criteria for evaluating the subject pilots in Study 4.

STUDY 4
VERBAL PROTOCOL ANALYSIS

The fourth study of the project consisted of a verbal protocol analysis based on the scenario and event analyses developed in Study 3. An experimental protocol, shown in Appendix C was established and administered to six subject pilots. These six subjects had not participated in any of the previous studies. The objective of this experiment was to gain further insight into the thought processes of expert pilots in an even more structured simulation scenario and to refine our model of the expert pilot in a form that could be tested in the next level of the study.

Subject Selection

The subjects for the verbal protocol analysis were six volunteer pilots from Florida and Ohio. Subjects were selected based on their availability and recent experience in one of the three domain aircraft. Most of the subjects were qualified in two or more of the domain aircraft. Although posting and word-of-mouth procedures were used to solicit pilot subject volunteers, all subject pilots were fairly well know to the experimenter. A summary of the demographic information about the subjects is shown in Table 4. Subject Pilots 1 and 2 fly for Part 135 operators, Subject Pilot 3 flies for a Part 121 operator and Subject Pilots 4, 5, and 6 fly for corporations.

Procedures

A "flight kit" with the applicable charts, aircraft manuals, supplies, and equipment to "fly" the scenario was brought to the experimental session as shown in Appendix C. Each subject was given the opportunity to request all of the items he would "usually" take on a trip of this type in the domain aircraft with which he was most familiar.

The scenario used (described earlier) was designed to be as close to realistic as possible through the use of repeated, actual experiences of the first author over the same route of flight in various weather conditions. The weather information package consisted of printouts of actual weather obtained for the experiment on a particular day for the flight. The flight plans were consistent across the three domain aircraft, changed only to reflect the type of aircraft being flown. In each case the subjects "flew" the aircraft in which they were most familiar.

When the subjects came in for their session, the protocol found in Appendix C was administered, beginning with filling out the human subjects approval form. All other paperwork was completed by the experimenter. The experiment was conducted identically in all cases with the subject completing the experimental scenario, then completing the Aviator Questionnaire. Prompting questions were used when necessary with approximately the same frequency for all subjects. At no time were the subjects instructed to "tell me why" or "tell me what you were thinking." All

questions were either for clarification of a statement or to continue the session. The entire process was tape recorded for transcription. All of the subjects were debriefed after the session and were given the opportunity to express comments regarding the procedure. The subjects reported that the process was both realistic and interesting.

The tape recordings of the sessions were transcribed and then coded into categories for data analysis. Any statement that could not be understood or was not clear was not coded. The coding was completed by the experimenter with one subject also being coded by an independent coder to check for coding reliability. The coding categories were then refined and the frequencies were compiled.

Data Coding

The initial verbal protocol analysis data coding categories were determined from the aviator cognitive analysis as well as the expert aviator models developed in Study 3. After completing the experimental protocol, transcription of the tapes, and encoding of the tapes, the coding categories were further revised to better reflect the information being presented by the subjects. The coding categories were as follows:

1. **Total Requests:** Total number of inquiries for supplies and all types of information.

   1.1 **Supply:** An item requested by the pilot to be used on the "flight" such as aeronautical charts, calculator, flashlight, etc.

   1.2 **Information:** This category is a total of all of the sub-categories of the types of information requested.

   1.2.1 **Weather:** Requests about the weather such as "What are the winds again?", "...ask them to check on the weather and see how bad it was...."

   1.2.2 **Position:** Requests regarding the subjects' position, or position of other aircraft. For example, "...see what kind of stack up...delays for other planes in the que...", or "..Try to get my new current groundspeed to find out if I'm going...."

   1.2.3 **Clarification:** A question of confirmatory nature such as, "It's called Allegheny County?", or "and this is an air traffic control problem?"
2. **Advise ATC:** The category is used when the subject indicated that he will inform air traffic control of the situation.
3. **Situation Evaluation:** When the subject is making comments (or questions) about the state of the aircraft, weather, air traffic, and considering the information available. "I could listen to the hydraulic pump and if the pump is still running..." and "First of all, I want to find out how much time I can expect to hold...."
4. **Curiosity:** A comment indicating the subject just wanted to know why in detail.
5. **Alternative Generation:** The verbalization of alternatives such as "If after my expect further clearance time, I would hold another half hour, if any longer, I'll go to my alternate."
6. **Action:** This category is used when only an action is stated as in "put the gear down."
7. **Total Statements:** This is the total of the subcategories below.

   7.1 **Procedural:** Comment on a procedure such as "well, the first thing you do is get out supplemental oxygen and it's a canister, it's not one you want to use unless you have to...". or "they usually figure 20-21 gallons per hour..."

   7.2 **System:** A statement regarding an aircraft or airspace system. "You have your upper and lower door to consider", and "the mains are down so there is no little mirror to check the nosegear..."

   7.2 **Experience:** A statement that based on the subjects' experience, past or during the experiment. "I usually file direct when I go up to that altitude", "You would have noticed it wasn't pressurized as you were going up, I would have noticed that right away", and "the forecast, 2,500 broken, but being as it is down now, and it may not come up...."

   7.4 **Error:** A statement that includes erroneous information, such as "I don't have the minimums for the approach".

   7.5 **Readback:** The repeating of a direction or statement by the subject.

   7.6 **Positional:** A statement on one's position for instance, "so I would be coming in from the northwest...."

   7.7 **General:** "A lot of thunderstorms" or "I would have highlighted this ahead of time..." are statements that are not specific enough to fall in any other category.

Table 1. Cognitive task analysis outline of seven flight events as a function of level of pilot competency.

	NOVICE			COMPETENT			EXPERT		
Events	Knowledge	Skills	Mental Models	Knowledge	Skills	Mental Models	Knowledge	Skills	Mental Models
Pre-flight	Weight and balance	Mathematical	Loading options	Gross weight	Addition	Understand limitations	Loading rules	"Shortcuts"	Conceptualization
	Fuel usage and calculations	Mathematical	Risk assessment	Center of gravity	Division	Moment/arm	Fueling rules		Personal limitations
	Aircraft performance	Chart usage	Set limits	Fuel density	Multiplication	Estimation	Interrelationship of weight and fuel load		"What-if" alternatives
	Fuel system/Gauges		Flight planning	Zero fuel weight	Subtraction	Load plan	Aircraft performance		
Landing gear abnormal on takeoff	Aircraft performance	Basic airmanship	Departure profile	Climb performance	Divided attention	Formulate options	Hazards of retracting gear	Using Checklists	Understanding Checklists
	Landing gear system	Operation of gear	Application of procedures	Shimmy dampener	Mechanical	Follow plan			
	Abnormal procedures			Weather	Instrument flight	Plan for approach			
Airframe icing in climb	Aircraft performance	Climb attitude	Climb profile	Typical climb performance	Recognition of performance	Conceptualization of Icing conditions	Expectation of performance	Vigilance	Expectation of Ice
	Weather	Evaluate conditions	Vigilant for icing	Symptoms of airframe Icing	Recognition of degradation symptoms				
	De-ice/anti-ice systems								
Hypoxia at altitude	Flight physiology	Use of pressurization system detection	Risks of flight at altitude	Oxygen needs in flight	Recognition of oxygen deficit	Vigilant for symptoms	Subtle symptoms of hypoxia	Immediate Correct Response	Dangers of Condition
				Cumulative effects			Differentiate from carbon monoxide		

Unexpected holding with turbulence	Flight planning	Flying a holding pattern	Position awareness	Holding entries	Navigation	Visualization of holding pattern	Expectation of holding	Prediction	Pre-Planning
	Maneuvering speed	Recognition of moderate turbulence	Limitations on turbulence	Holding patterns	Procedural	Use of recommended speeds			
	Weather	Types causing turbulence		Flight load limits	Memorization				
				Fuel state	Fuel scoring	Minimum fuel			
Windshear on approach	Understand the weather:Winds, temp./dewpoint, thunderstorm	Localizer tracking	Formulate Options	Convective activity	Basic airmanship	Avoid areas of known windshear	Integration of windshear knowledge	Refined techniques for shear encounters	Novice-to-expert model progression
	Recognize the windshear potential PIREPs	Glideslope tracking	Performance limits	Gusty winds	Windshear recovery techniques	Score shear potential			Refine expert model
	Aircraft performance	Stall recovery/ windshear recovery procedures	What-if diversion plan	Temp/dewpoint greater than 20 deg.		Ask for winds			
				Reported windshear by pilot or controller		Plan diversion or hold			
Abnormal gear indication on landing	Landing gear system	Divided attention	Approach profile	Alternate gear extension procedure	Application of procedure	Understanding of procedure	Abnormal situations	Focused Attention	Prioritization of Procedures
	Missed approach procedures	Basic instrument flying skills	Missed approach procedure	Standard approach profile	Glideslope tracking	Performance parameters	Terminal traffic flow		Situational Visualization
				Air traffic control system					

Table 2. Factors making up the general expert mental model of aviators

SITUATION ASSESSMENT

AIRCRAFT CONDITION DATA	POSITION DATA	FLIGHT PLAN	AIR TRAFFIC CONTROL
System Condition	Altitude	As Filed	Volume of Traffic
Fuel State	Airspeed	Deviations	Potential Conflicts
Abnormals	Configuration	On Schedule	
Emergencies			
Airframe Status			
Engine Status			

CONDITIONS

WEATHER FACTORS	NAVIGATION FACILITIES	PILOT FACTORS	AIRCRAFT FACTORS
Winds	VOR	Fatigue	Current Condition
Turbulence	ADF	Personal Factors	Aircraft Limitations
Icing	GPS	Crew Coordination	
Thunderstorms	DME	Personal Limitations	
Temperature	LORAN		
Dewpoint	ILS		

PREREQUISITE INFORMATION

SKILLS	KNOWLEDGE	DECISION-MAKING SKILLS
Gross motor skills	Aircraft	Problem Solving Strategies
Perceptual-motor	Environment	Creativity
Perceptual	Pilot (self)	Prioritization
Procedural	Limits	Compartmentalization
Decision Making	Time Management	Curiosity
Time sharing		
Skill Integration		
Limitations		

Table 3. Model of the competent and expert general aviation pilots

COMPETENT PILOT	EXPERT PILOT
KNOWLEDGE	
Knows the domain sufficiently to pass FAA exams	Knows the domain Knows him/herself Knows the environment Knows the organization
SKILLS OR ABILITIES	
Skills and abilities sufficient to pass FAA exams	Highest technical skill Superior mental abilities for problem diagnosis, risk assessment, and problem resolution Ability to focus attention Ability to change focus of attention Adaptable communication skills
BEHAVIOR	
Usually follows FARs Takes the BFR and IFR proficiency tests	Avoids situations that push skill Keen observer of the flight environment Establishes baseline for normal operations Makes contingency plans Works continuously to improve knowledge, skill, and abilities
MOTIVATION	
May be primarily focused on matters outisde of cockpit	To continuously learn about domain To be skeptical about "normal" situation To overcome pressures to push risk To change focus of attention when needed

Table 4. Pilot demographics

	S1	S2	S3	S4	S5	S6
Age	26	24	50	55	54	49
Flying Years	8	5	29	25	5	10
Total Time	2600	2600	10600	14000	2000	2200
Instrument Time	130	110	850	300	200	600
Domain Aircraft Time	600 (C)	500 (C)	35 (P)	350 (B)	200 (C)	115 (P)

(C=Cessna 210, P=Piper Malibu, B= Beech Baron)

8. **Decisional:** A comment which states or implies a decision, or decision process such as "Since I had trouble with the shimmy dampener, I would probably figure it wasn't a false indication...", "I don't know if I'd go in this weather, tornadoes, thunderstorms...", and "There's some amendments in there, so may have to worry about it changing as we go down there, but generally it's workable."
9. **Decision Process:** This category usually consisted of a lengthy evaluation and explanation of a situation outlining the plan or system used in making a decision. This differs from the Statement, Decisional in the complexity of the discussion and number of alternatives, statements, and evaluations made in succession. An example, "Well, first consideration would be is if we encounter windshear on the approach, execute the missed approach and proceed to the alternate, have time check out the alternate weather and come back to Charlotte when it is suitable, That would be my plan. I'd go ahead and attempt the approach, but at first indication of windshear that was unacceptable for this aircraft, I'd go ahead and skip this and go to the alternate."
10. **Decision:** This is the number of instances in which it was clear that a decision has been made as in "I will come back and land," or "Then it was down and I'd go back to Charlotte."
11. **Total Decision Making:** This is the sum of the Statement- Decisional, Decision Process, and Decision categories for use in data analysis. The purpose of the category is to look at the total number of events concerned with decision making.
12. **Expert Rating:** This is a subjective rating made by the experimenter of how closely the subjects' known flying behavior approximates that of the 10 characteristics of the expert aviator defined in Study 2. Although it would have been desirable to have multiple raters, only one was used. This decision to use only one rater reflects both the logistical difficulties of locating other raters in the various places where data were gathered and the exploratory nature of this study. Given the nature of the study and the overall intent of identifying as opposed to measuring components of the pilot expertise model, the use of single rater provides a sufficient though certainly not optimal approach.

Data Analysis

Phrases, ideas and statements were encoded from the transcripts and compiled for the coding categories listed above. The primary goal of the analysis was to show the level of correspondence between the hypothesized model of the expert aviator and the data from these pilot experts. Specifically, the three hypotheses that were tested were: 1) Expert pilots seek more quality information in a more timely manner, (i.e. they know what to ask for and when to ask for it) than competent pilots, 2) Expert pilots make more decisions than competent pilots, 3) Expert pilots communicate more readily with all available resources.

These three areas were expected to contribute insight into decision making and thought processes as observed during the problem solving experiment. The first analysis examined the number of statements made in each category by each pilot subject. The second analysis was a subjective evaluation by the experimenter of each pilot subject based on independent knowledge of the pilot.

Results

To evaluate the first hypothesis (information gathering) the type and number of requests for information or material made by the subjects was used. As shown in Figure 2, Subject 3, and to a lesser degree Subject 5, have a noticeably larger number of informational requests than the other subjects. On closer observation of each individual subject with respect to task, these same subjects also seemed to ask more appropriate questions in each of the circumstances.

The second hypothesis (decisions) was evaluated initially using the Decision frequencies. In this case, the data show that Subjects 3 and 6 made the most decisions. To provide a more robust score, it is useful to combine the three categories of Decisional Statement, Decision Process, and Decision into a Total Decision score. Using this Total Decision score, Subjects 3 and 6 have considerably higher scores than the others (See Figure 3). These two subjects tended to verbalize their decision-making processes in much greater detail than the other four subjects. These subjects also used a type of dynamic problem solving which helped to direct us toward our final model of the expert pilot (see Figure 6), including satisficing, feedback, and keeping their options open.

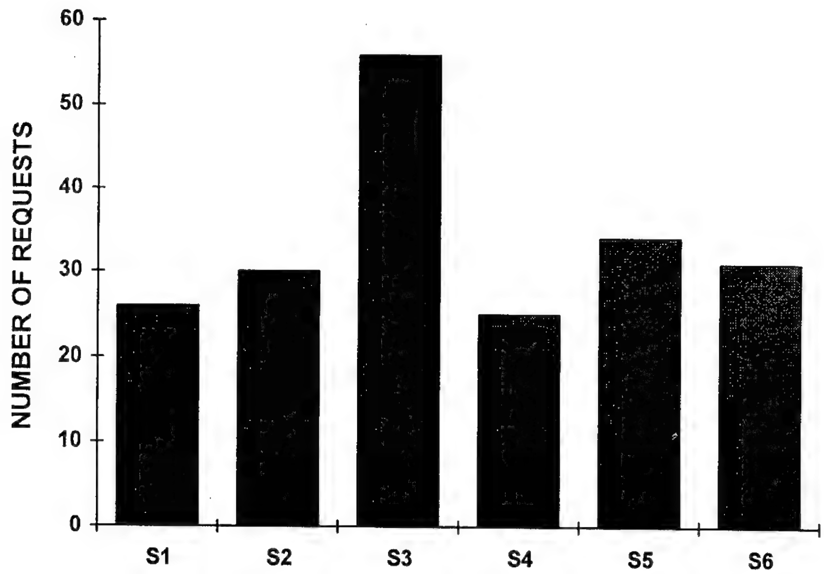

Figure 2. Number of requests for information by each of the six subjects

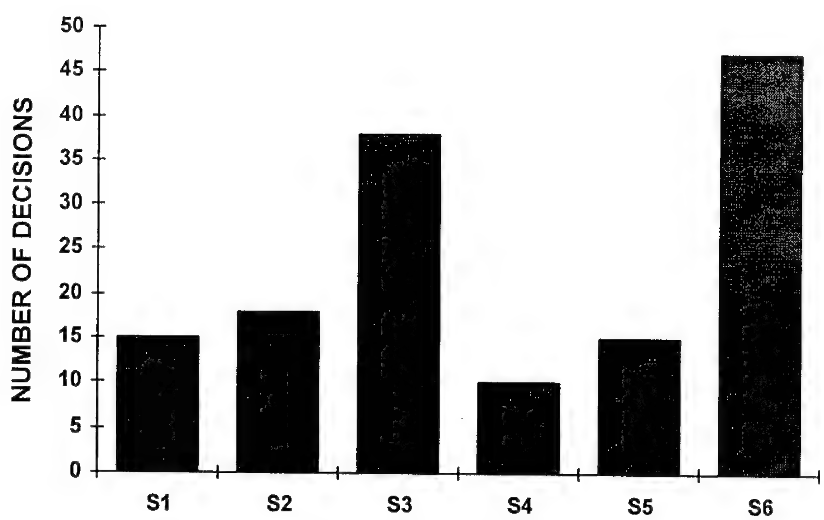

Figure 3. Total decisions by each of the six subjects

To examine the third hypothesis (communications), type and number of statements made throughout the simulated flight were used. Again, Subjects 3 and 6 made more Total Statements (see Figure 4). All types of communication (verbal, non-verbal, tactile) are critical in pilot duties. The pilot judgment literature and cockpit resource management training courses emphasize communication skills as one of the primary components of a safe and effective pilot (Jensen, 1995). Although the data from this study suggest that being able to verbalize the rationale for actions and a propensity for seeking (verbally) more information are associated with pilot expertise (as defined here), generalizing from such a small sample is clearly a risky affair. Further, other studies of expertise using other domains (Ericsson and Smith, 1991) have generally found that experts are unable to verbalize the reasons for their actions because of the high degree of automaticity that has developed. The data collected here do not provide us with a means to explain why the character of expertise in aviation should differ from the character of expertise in other domains. The present results are suggestive, but certainly not compelling, and will be explored further in subsequent, more closely controlled studies of larger groups of expert and novice pilots.

"Expert" Rating

The second method for determining expertise, sometimes used in the literature is the peer rating (Ericsson and Smith, 1991). In this study an expert observer (the experimenter), who was also a peer of all six subjects, provided a subjective "expertise" rating on each of the 10 characteristics of the expert aviator developed in Study 2: Self-Confidence, Motivation, Practice, Focused, Situation Awareness, Information Seeking, Prompt Action, Vigilant, Communication, Sets Limits. Each of the subjects was rated on a scale of 1 (lowest) to 10 (highest) for each of these ten factors. The experimenter used information known about each subject independently from the experimental data to make these ratings and performed the ratings prior to the experimental data collection. Table 5 shows how each of the six subjects was rated on each of the ten factors. A summary of the conditions considered in the expert model vs. the expertness rating is depicted in Figure 5.

Although all six subjects were rated high in most categories, Subjects 3 and 6 were rated more highly than the other four on this single-rater peer rating scale. These data tend to confirm the more objective verbal protocol results shown in Figures 3 and 4. As one would expect, there appears to be no relationship between the expert rating and either flying experience or number of flying years (See Table 4).

In this final study an attempt was made to differentiate among pilots who were known to be above average using both verbal protocol analysis of a verbal flight simulation and expert ratings. The results suggest that one can discriminate among the pilots using this procedure. However, an open-ended verbal simulation leaves questions concerning the use of verbal communications as a measure of expertise. Although pilots are taught to communicate, and expert pilots do communicate very well, this is not the only criterion for pilot expertise as shown in the final model.

The results tend to indicate that pilots have different methods and styles for solving fairly common flying situations, and these methods are not related to the total flight time or number of years flying. Subjects 3 and 6, who were rated the highest, consistently made initial, rapid assessments of situations and then proceeded to confirm or disprove their theories. The other subjects usually asked for some other type of information, or made other unrelated statements before handling the presented problem. Finally, these two subjects were far more verbal and tended to talk in paragraphs while the others typically offered only one or two short phrases. Although this may reflect different personality styles, the content of communication from these two subjects was more consistent with the expert model than that of the other subjects.

Table 5. Subjective rating of expertise for the six subjects

Factor	Subjects					
	S1	S2	S3	S4	S5	S6
Self-Confidence	5	5	9	7	8	9
Motivation	10	6	9	9	9	9
Practice	9	7	9	8	9	9
Focused	7	7	8	6	7	7
Situation Awareness	5	5	10	6	7	9
Information Seeking	10	8	8	7	8	9
Prompt Action	2	4	10	6	7	8
Vigilance	4	5	8	6	7	8
Communication	5	6	10	7	8	9
Sets Limits	5	6	9	7	7	7

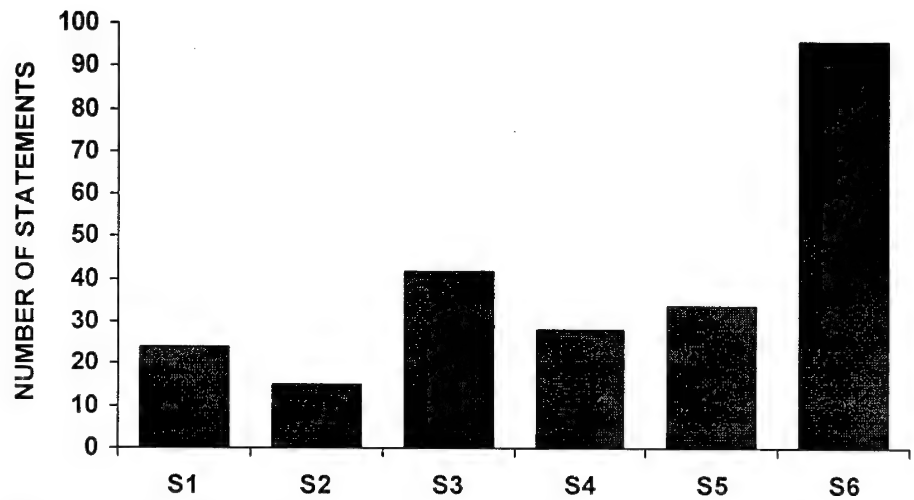

Figure 4. Total number of statements by the six subjects

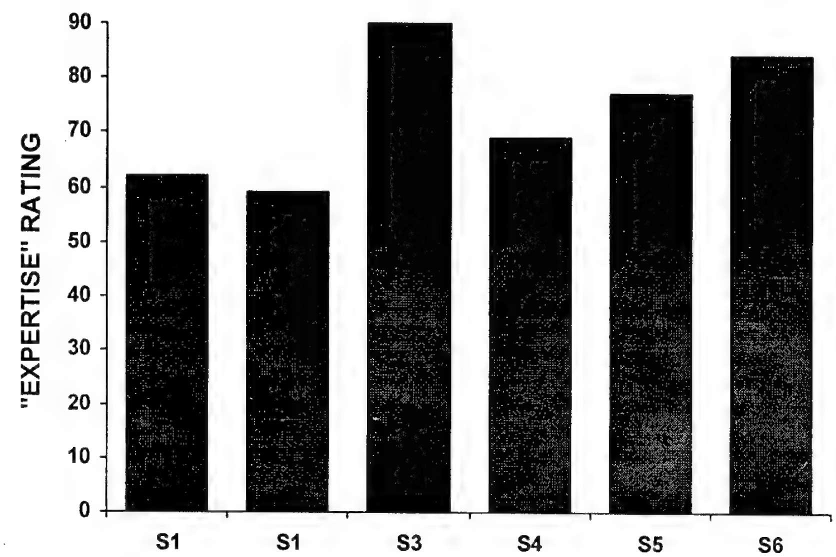

Figure 5. Combined rating of expertise for the six subjects

SUMMARY AND CONCLUSIONS

The objective of these four studies was to develop a model of the expert pilot decision maker and to show how it could be used to develop intervention strategies to improve safety in the target population of mid-altitude general aviation pilots. To accomplish this objective, NTSB accident reports were analyzed for the domain aircraft, the relevant literature on decision making, expertise, and modeling was reviewed, and four studies were conducted including semi-structured interviews, structured interviews, cognitive task analysis, and verbal protocol analysis of a simulation experiment. Following each of these studies, new insight was gained and modifications were made to the model of the expert pilot decision maker.

The results of this series of studies suggest that expertise in general aviation may have very little relationship with flight time after a certain number of hours (perhaps as low as 2,000 hours). In general the primary characteristic distinguishing the expert from the competent is judgment. More specifically, we propose that expertise in general aviation pilots can be defined in terms of the following ten characteristics:

1. Self-confidence in his or her skills as a pilot,
2. Motivation to learn all there is to know about the flight domain and practices their skills constantly,
3. Ability to focus on the necessary task and change that focus at the slightest hint that a change is needed,
4. Situation awareness (flight environment, location of other aircraft, terrain, navigation, communications, weather, etc.),
5. Cognizant of the machine including noise, vibration, and engine indications,
6. Vigilant for the unusual, abnormal, or emergency, and mentally makes contingency plans,
7. Mental capacity for problem diagnosis, risk assessment, and problem resolution,
8. Communication skills and applies those skills to each audience and situation,
9. Knowledge of his or her own limitations and motivation to keep a safe margin above those limits, and
10. Ego-strength to enforce his or her own limitations in every situation.

Based upon the data from the studies described here, and taking into account the large body of research on pilot performance along with his own insights into pilot decision making, Jensen (1995) proposed a general model of the expert pilot which is shown in Figure 6. The characteristics of expertise in general aviation pilots suggested above might be described in terms of experience, risk management, problem solving and attentional control and aggregated into Jensen's larger, more general model of the expert pilot. In that model the major factors contributing to pilot expertise which subsume the findings of these studies are:

Aviation Experiences. Proponents of the expertise approach to studying human behavior have indicated that expertise is gained through years of experience. They often say that 10 years of experience dedicated to one field makes an expert. Some have used hours of experience in flight as an indication of expertise. Jensen believes, as do almost all other researchers in this field, that it takes more than hours of flying experience to make an expert pilot. In this step he proposes that there are five aspects of experience that are necessary to fulfill this part including, number of hours, variety, meaningfulness, relevance, and recency. Many hours of flight in Ohio does not make an expert pilot in mountainous terrain — a variety of experiences is need. Experiences that have no meaning (e.g., boring lectures) do not change behavior — the experiences need to be presented in ways that are meaningful to the learner (e.g., experiences with sound, visual effects, motion — simulation). The experiences must be relevant to the kind of flying that is anticipated of the expert (e.g., in teams if for a multi-person crew aircraft). Finally, the experiences must be recent. Although some experiences remain in one's mind for life, most need to be reinforced periodically to be available for expert decision making.

Risk Management. The second step in creating the expert pilot decision maker is to develop risk management techniques. This step requires the establishment of a proper set of values consistent with societal norms (i.e., the pilot must know the safety expectations of his passengers and company). It also requires that the pilot studies carefully all of the possible hazards and the probability that these hazards could affect his flight practice.

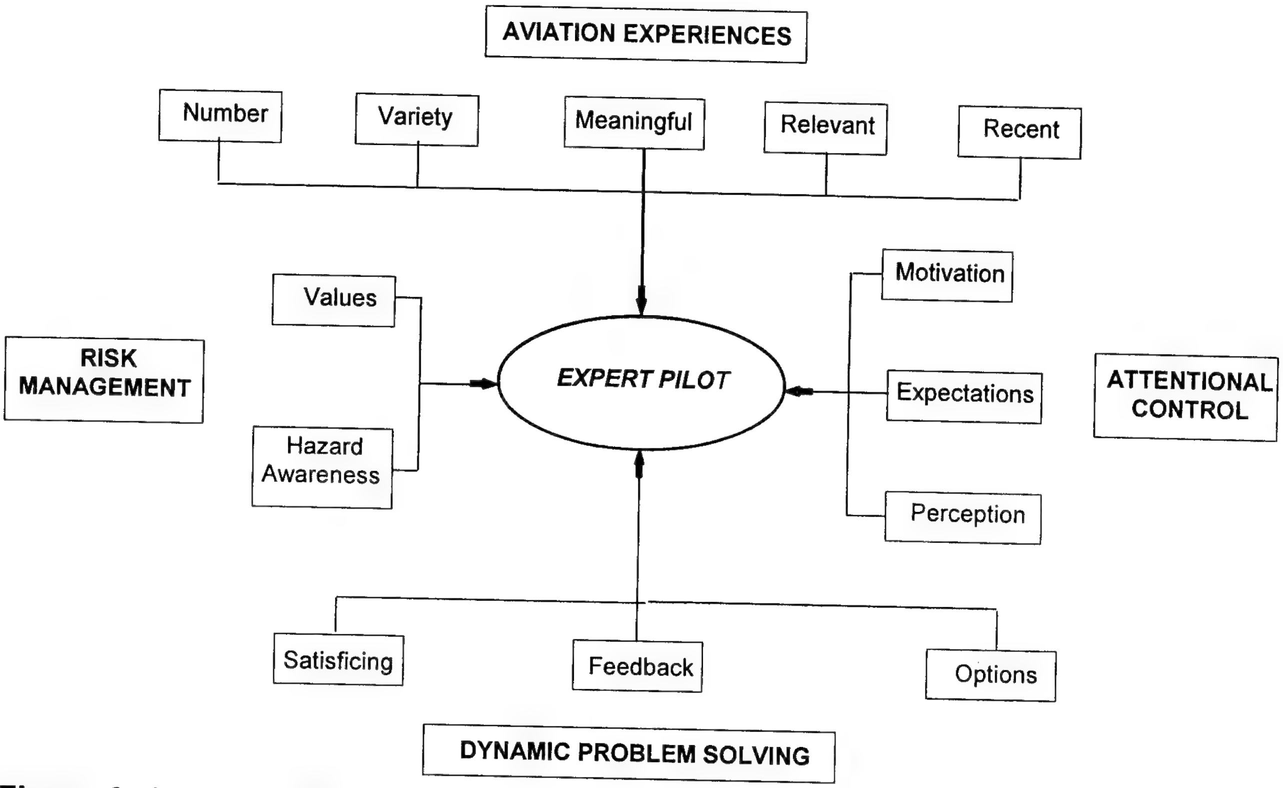

Figure 6. Jensen (1995) model of the expert pilot decision maker.

Dynamic Problem Solving. The third step is to develop a technique for solving dynamic problems known as satisficing. This technique for solving ill-defined problems, which has been identified in experts, consists of beginning with a clear understanding of the situation and making decisions that have a good chance of leading to the optimum solution, always keeping the safest options open. Feedback from the action is used to gain further information leading to additional decisions. Finally, the optimum choice is made. The key is to make decisions that avoid closing options.

Attentional Control. The final step is to develop an ability to control attention so as to focus on the task at hand leaving all other matters out of mind. In conjunction, the expert pilot must also be able to perceive the smallest indication that something else in the cockpit deserves his attention and switch to that matter quickly and deliberately. It means being able to put matters outside of the cockpit out of your mind as well. Finally, it means not allowing pressures to make decisions based on non-aviation concerns to influence you away from the safe choices for which you are committed (Jensen, 1995).

This model provides a framework for understanding the results of the current series of studies. It also provides a rational platform for planning further studies directed at a better understanding of pilot cognition and behavior. From that understanding we believe will come new training interventions to produce safer general aviation pilots.

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APPENDIX A

INITIAL SEMI-STRUCTURED INTERVIEW QUESTIONNAIRE

The Ohio State University Department of Aviation is investigating enhanced training methods for the Federal Aviation Administration through FAA Contract No. DTFA01-92-10204. We are asking your cooperation in this brief interview to assist in the definitions and terms to be used in this project. The personal data and information you provide is confidential and will only be used to contact you in the future if you would like to participate in another phase of this project. Your time and comments are most appreciated.

1. How can you distinguish how "good" a pilot is?
2. If you were to group pilots into three categories based on how "good" they are, what would you name the categories?

    a.
    b.
    c.

3. What did you base your categories on?
4. Describe a type "a" pilot. Can you name three?
5. Describe a type "b" pilot. Can you name three?
6. Describe a type "c" pilot. Can you name three?
7. What is the best maneuver to use to determine how "good" a pilot is? Why did you choose this one?
8. Name the three most memorable events you have had as a crewmember in any aircraft.
9. Would you be willing to participate in future phases of this project?

APPENDIX B

AVIATOR STRUCTURED INTERVIEW

AVIATOR QUESTIONNAIRE

Dr. Richard S. Jensen, myself, and The Ohio State University Department of Aviation is investigating enhanced training methods for the Federal Aviation Administration through FAA Contract No. DTFA01-92-10204. We are asking your cooperation in this brief interview to assist in the definitions and terms to be used in this project. The personal data and information you provide is confidential and no information associated with you or your responses will be released. This information will only be used for our research purposes, and to contact you in the future if you would like to participate in another phase of this project. Your time and comments are most appreciated.

The questionnaire is given verbally and your responses will be recorded and transcribed at a later date. There is a standard consent form we as you to read and sign before you participate in the project. If at any time you wish to discontinue participation in this study for any reason, simply state you would like to stop, and you may do so without question. I will be glad to answer any questions you have before or after the interview.

1. Why did you become a pilot?

2. What are your best attributes as a pilot?

3. What kinds of experiences, either in training or in other instances have made you a better pilot?

4. Name the three most important skills that are components of your task as a pilot.

5. Describe two events you consider to have been critical in nature while flying.

6. How might you have responded to the above situations differently?

7. What one factor makes a pilot above-average compared to other pilots of their status?

8. What is the most difficult aspect of flying a ____________(P-210, Malibu, P-Baron)?

SUBJECT INFORMATION

DATE OF INTERVIEW: INTERVIEWER:

AGE: TOTAL YEARS FLYING (Full Time): CURRENT: YES NO

WOULD YOU BE WILLING TO PARTICIPATE IN OTHER PHASES?
WOULD YOU BE WILLING TO FLY IN A SIMULATOR?

NAME____

ADDRESS____

TELEPHONE (H)______________(W)________________

EMPLOYER_______________________________________

PILOT CERTIFICATES/RATINGS____________________

AIRCRAFT OWNED (CURRENT)________________(PREVIOUS)__________________

FLIGHT TIMES:

TOTAL ______________ INSTRUMENT ________________ NIGHT _______________

TIME IN TYPE:

CESSNA P-210 __________ PIPER MALIBU __________ BEECH BARON __________

TRAINING: LAST TRAINING SESSION (date and place) __________________________

TIME SPENT IN AVIATION ACTIVITIES PER MONTH ___________________________

PURPOSE OF FLYING:
____%FOR HIRE (type):____%PERSONAL ____%BUSINESS ____%FUN _______

APPENDIX C

EXPERIMENTAL PROTOCOL

Experimental Kit Checklist:

1 Jeppesen Sandersen Flight Case
Jeppesen and NOAA Low and High Altitude Enroute Charts
Jeppesen and NOAA SIDS, STARS, and Approach Charts
Applicable Sectional Charts (Detroit, Cincinnati, Charlotte)
Airman's Information Manual
Federal Aviation Regulations
1 D-Cell Flashlight
2 E6B Flight Computers
Aircraft Flight Manuals (Cessna 1978 Pressurized Centurion, Piper Malibu, Beechcraft Pressurized Baron 58P and 58PA)
1 Calculator
1 Voice Activated Tape Recorder (with spare tapes)
Pens and Pencils
2 Copies of Written Weather
Flight Plans and Flight Logs for C-210P, PA-46P, and B-58P)
Human Subject Consent Forms
Subject Information Forms
Verbal Protocol Scenario Script

VERBAL PROTOCOL

<u>SUBJECT PRE-BRIEFING</u>

"Dr. Richard S. Jensen, myself, and additional members of The Ohio State University Department of Aviation are investigating enhanced training methods for the Federal Aviation Administration through Contract No. DTFA01-92-10204. Thank you for agreeing to participate in our study.
This portion of our study will involve reading you a common situation you may encounter while flying your ___________. This session should not last any longer than 2 hours. The background of this session is a flight from AGC (Pennsylvania) to CLT (North Carolina) for a business meeting. Before we begin, you will have the opportunity to request information, charts, equipment, and supplies that you would normally take on an IFR flight in your _______________. There are six different flight segments that I will read to you. After listening to the segment, I would like you to tell me in detail what you would do.
The session will be tape recorded, but as explained on the consent form, your name will not be used or kept with the information from the study. The responses and data that you provide is confidential, and no information associated with you or your responses will be released. If at any time you have a question regarding the study, please feel free to ask. If at any time you wish to discontinue participation in this study for any reason, simply state you would like to stop, and you may do so without question. After the session, we will debrief in full and review the flight segments. Do you have any questions before we begin?"

FLIGHT REGIME FOR SCENARIO DEVELOPMENT

The following flight segments were selected from a theoretical flight from the Allegheny County Airport (Pittsburgh, Pennsylvania) to the Charlotte-Douglas International Airport (CLT) in Charlotte, North Carolina. This flight was to take place in the summer with marginal weather at AGC and deteriorating weather enroute to CLT due to a fast moving cold-front approaching the Appalachian mountains. The route of flight and weather pattern development were constructed to facilitate realism in the flight segments that follow.
The subjects in the experiment will be given a prepared flight plan (IFR) and an opportunity to make changes to the plan. They will be allowed to request the necessary equipment, charts, and other information they would normally have on a trip of this type. The background information given to the subjects includes a brief discussion of the flight. Supplies requested that are not available will be recorded as such. Decision trees and analysis will be based on consistent procedures and information from the experimenter/"air traffic controller". The available equipment and information is listed below followed by the flight plan, flight log, and weather for the scenario.

Supplies Available to Subjects:

1. Pilot Operating Handbook for Cessna P-210, Piper PA-46, or Beechcraft P-58.

2. Low and High altitude enroute charts, either NOS or Jeppesen.

3. Sectional and/or WAC charts.

4. Approach charts, either NOS or Jeppesen.

5. Flashlight.

6. Flight plan (already completed).

7. Flight log (already completed).

8. Weather - printed SA, FT, FA, winds aloft, NOTAMS, and SIGMETS.

9. Information regarding aircraft equipment and status.

10. Airman's Information Manual/Federal Aviation Regulations.

Flight Plan:

IFR flight, N527JK, PA-46, C-210P, B-58P, all /R (RNAV equipped), 200kts true airspeed, departing AGC, at 1600 UTC, cruising FL200, route of flight filed direct, CLT. Time enroute 2 hours, fuel on board 4 hours, alternate GSO, 4 souls on board, aircraft is white with red.

Flight Log:

Although the flight is filed "direct", the route of flight proceeds from Allegheny County (AGC), Parkersburg West Virginia (JPU), Charleston, West Virginia (HVQ), Holston Mountain (HMV), the Shine 5 arrival into Charlotte (CLT).

Weather for Flight Scenarios

Actual printed weather packets were issued to each participant in the study using standard NOAA format.

PRE-FLIGHT TASK - Weight and Balance and Fuel Calculations

Prior to starting the scenario, the subjects are told that the flight plan and flight log have already been prepared (including four hours of fuel). They are asked to "check your weight and balance" (there are four souls on board at 170 pounds each and 25 pounds of baggage each) and asked if they want to make any changes to their flight plan or fuel loading. The tape recorder is voice-activated, so a note of the preparation time is made for each subject.

After the subject completes the pre-flight tasks as requested, the scenario segments are started. The text of the segments follow. Statements in parenthesis are notes for the experimenters' use only.

TASK 1 - Nosewheel Shimmy on Take-Off

"You are departing on RWY 23 at AGC. Just before rotation there is a considerable nosewheel shimmy. After retracting the landing gear, the red 'gear unsafe' light(s) remain illuminated.

How will you handle this situation?"

TASK 2 - Airframe Icing

"You are climbing through FL 180 and have been IMC since passing through 4000 feet MSL. You notice the aircraft is not climbing as well as it should for the weight. You also notice a strange whistling sound and are not able to determine where it is coming from.

What are your actions?"

TASK 3 - Subtle Cabin Pressure Loss at Altitude

"You have been cruising at FL 200 for about an hour. The weather is still IMC, but it is now -9 degrees C and the ice accumulation has stopped. The unforecast headwinds and vectors you have been given has added about 20 minutes to your flight time. You feel your ears popping and wish you could get rid of a nagging headache. You are given a frequency change to Indianapolis Center and fumble with the radio controls. After contacting Center, you find yourself laughing at the controllers' instructions to turn 30 degrees left for traffic. You are on autopilot, initiate the turn and finally scan your gauges. It seems to take a long time to comprehend what they are reading.

What will you do now?"
(To what altitude will you descend?)

TASK 4 - Unexpected Hold (including moderate to severe turbulence)

"You are approaching the HMV VOR and thinking to yourself that it hardly pays to file direct anymore. You have been vectored all over the place, the weather is not the greatest, and apparently you are catching up to that cold-front as the ride is getting pretty rough. You have to ask your front seat passenger to hold your charts as they will not stay on the chart holder. Center calls with an amendment to your routing when you are ready to copy as follows:______________, you are now cleared direct to the HMV VOR, hold NE on the 012 degree radial, maintain ________(altitude). This is for flow control into CLT. You read back the clearance and inform your passengers of the delay.

What are your actions now?"
(Expect Further Clearance Time 1815, Time Now 1743)
(When finished, give heading 180, vectors for Charotte)

TASK 5 - Windshear Recovery on Approach

"You are now 30 miles from the Charlotte airport at __________feet and just received the ATIS as follows: "Charlotte-Douglas International Airport information Whiskey, 1950 special weather, sky partially obscured, visibility one and one-half miles, thunderstorm, rain-showers, temperature 63, dew-point 61, wind 200 at 12, peak-gusts 25, altimeter 29.83. Expect ILS 18L or ILS 18R. Low-level windshear advisories in progress. Notams, RWY 18L glide-slope out-of-service. Advise you have Whiskey". Indianapolis center tells you to contact approach. You change frequencies and are given a vector for the approach to 18L and are advised that a USAir DC-9 reported minus 15 knots on the approach to 18R.

What considerations will you make regarding this approach?"

TASK 6 - Abnormal Gear Extension

"You have been cleared for the approach to RWY _________. Following your normal procedures, you put the gear handle down, and discover the red "gear unsafe" light(s) are still illuminated.

What will you do next?"
(When do you normally put the gear down?)
(Gear Lights: Cessna - 1 Red, Piper, 2 Green for Main Gear No Nosegear indication, Beechcraft - 3 green down-lock lights, 1 red "unsafe")

SUBJECT DEBRIEFING

Prompting questions for each segment:

1. What other information would you request?

2. Tell me how you came to that conclusion.

3. What factors are most important in your decision to ___________?

4. Could you tell me in more detail why you ______________?

5. Please elaborate.

POST SESSION DISCUSSION

1. Where did you get your information/training in these areas?

2. Have you ever been in similar situations?

    a. Which ones?

    b. Tell me about your experience.

3. Do you have any questions?

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